Advanced Stochastic Network Models Of The Impact Of 4D Aircraft Trajectory Precision

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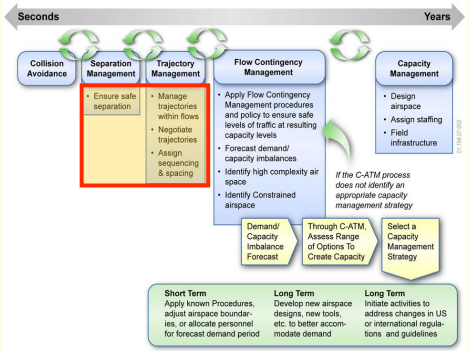
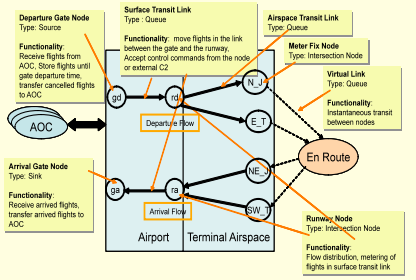
Background-Motivation



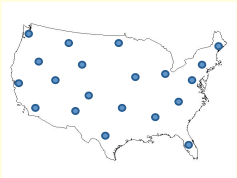
Trajectory-Based Operations	• Flights are managed via verbal delivery of clearances and vectors. • Time-based metering is used in some localities to improve predictability and throughput. • Required navigation performance (RNP) operations are used initially to manage complexity and increase capacity.	• Flights are managed through use of 4DTs that specify accurate current and future aircraft position. • Metering, controlled time of arrival (CTA) exchange, and more flight-specific adjustments increase overall throughput and operator efficiency. • Safety, security, and environmental considerations are integrated in TBO. • Flight crew–initiated, dynamic trajectory adjustment is possible with ATM and airport operations center (AOC) collaboration.

Simulation and Validation

Develop a Queuing Network Representation of the National Airspace System (NAS) Network Consisting of the Busiest Airports and their Associated Traffic



National Representation



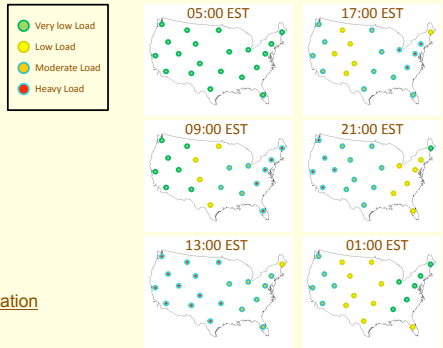
Research Objectives

- Develop Queuing Models that Predict Benefit of Increased Aircraft Trajectory Precision
  - Reduced inter-arrival time
  - Reduced variation in inter-arrival time
  - Reduced service time
  - Reduced variation in service time
  - Increased number of servers
- Develop Modeling and Visualization Environment to Allow
  - Validation of Queuing Model Results Against Simulation
  - Visualization of Benefit Mechanisms
- Validate Proposed Queuing Models
- Apply Validated Models to Next Generation Air Transportation System (NGATS) Concepts

Visualization

Develop an Interactive Tool to Facilitate Visualization of the Ways that Trajectory Uncertainty Propagates

Visualization of the Time-Evolution of the Load on the National Airspace



Local Representation

Next Steps

- Ensure results of queuing models are fully comparable with respect to how delay profile is constructed
- Run Airspace Concept Evaluation System (ACES) with arrival capacity constraints
- Increase complexity of ACES runs
  - Departure capacity constraints
  - En route capacity constraints
  - Network effects

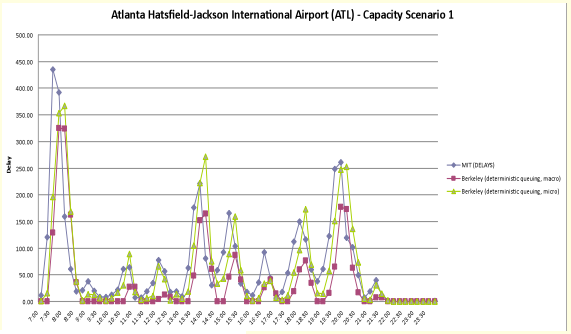
Modeling the Levels of Aircraft Trajectory Uncertainty

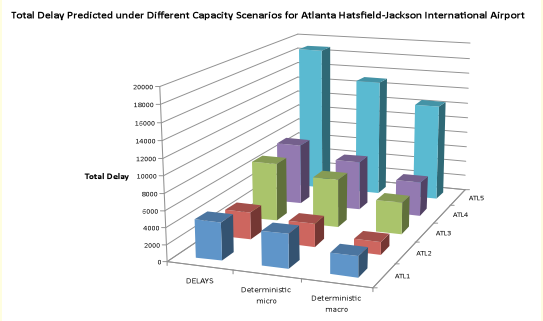
- Low Precision Case: Stochastic Queuing Models
  - Captures present-day system
  - Arrivals are time-dependent Poisson process
  - Service times are time-dependent Erlang *k* process
  - Employ previously developed DELAYS & Approximate Network Delays (AND) models
- High Precision Case: Deterministic Queuing Models
  - Given
    - Arrival schedule (aggregate or disaggregate)
    - Capacity or deterministic minimum headways
  - Construct cumulative arrival and departure curves to obtain
    - Delay and queue length by time of day
    - Average and total delay
- Intermediate Case: Diffusion Approximation
  - Dynamics of joint probability density functions are analogous to dynamics of physical flows or other density problems
  - Continuous approximations using systems of coupled partial differential equations
  - Because derivatives of probability density functions are modeled, they can be integrated to produce moment estimates

Application and Results

Comparison of Delay Predicted by Stochastic and Deterministic Models for Atlanta Hatsfield-Jackson International Airport (ATL) under Different Capacity Scenarios

- Delay build-ups predicted by deterministic model lag delay build-ups predicted by stochastic model





- Stochastic delay model predicts higher average delays
  - 11%-25% higher
  - Differences generally greater on low capacity days
  - Greater differences in peak delays